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METHOD OF AND DEVICE FOR DETERMINING A POSITION OF THE SOLIDIFICATION POINT IN A STRAND DURING CONTINUOUS CASTING OF LIQUID METAL, IN PARTICULAR LIQUID STEEL

The invention relates to a method of and a device for determining a position of a solidification point in a strand during a continuous casting of liquid metals, in particular liquid steel, in which a strand formed in a continuous casting mold as a billet, ingot, bloom, preliminary section, thin slab, or slab strand, is displaced in support roller segments, is cooled, and is drawn out by support roller segments with driven support roller pairs. During production of above-mentioned elongate products with a continuous casting method, the cast initial material should meet high requirements with respect to its inner quality. Of large importance is as uniform as possible distribution of alloy elements over the entire strand cross-section, without a damaging segregation that may occur in the strand center and in inner cracks.

Knows is an electromagnetic stirring process in which a strand stirrer operates in the region of final solidification, and the time at which the desired action of the stirrer should reach the core melt, depends on the position of the solidification point. Because the solidification point is not known or is uncertain, in all cases, displacement of the device in the strand displacement direction is necessary.

Also known is a so-called soft-reduction process in which the strand thickness is reduced in the region of final solidification to thereby press back residual melt enriched with alloy elements. The known method aims at circulating or distribution of the core melt.

It is, therefore, necessary to be able to determine the solidification point length as precisely as possible. To this end, a calculation model was developed based on relevant data such as, e.g., casting speed, amount of cooling water, kind of steel, or steel entry temperature.

The precision of the calculation model depends on the reliability of the available process data and on the influence of non-model-forming process parameters. To this, changes in physical characteristics of the strand or other process variables should be taken into account. Thus, elasto-plastic behavior of a completely solidified strand differs from that of only partially solidified strand. Also are available other methods of determining the degree of solidification such as, e.g., determining the force of drawing out the strand through the support roller system of a continuous casting machine, and measuring the support force at segment or driven rollers (EP 1197007 A1).

The object of the invention is to achieve a determination of the position of the solidification point in a strand more precise than with all of other known methods.

The object of the invention is achieved according to the invention in that an indirect measurement of a movable amount of a core liquid volume per unit of length is carried out by direct measurement of generated process parameters by force and/or path signals on fixed or adjustable individual support rollers or groups of fixed adjustable support roller pairs, and based on the measurement values, a calculation model for a momentary position of the solidification point is produced, based on which, changeable casting parameters are continuously adjusted. The principle is based on changing or displacing the liquid volume during otherwise constant casting conditions by specific movements of support roller segments or individual support rollers or other elements at different points along the strand displacement from a region immediately below the continuous casting mold up to the maximal theoretical point of complete solidification of the strand. Thereby, it can be particularly determined whether the strand still has, at a predetermined time point at a predetermined location, a liquid core, smaller or greater partial solidification or has completely solidified.

According to an embodiment of the invention, it is contemplated that the measurement signal is based on a local change of the strand thickness. This measure can be advantageous in many applications:

With formats for slab, ingot and billet strands, a local change of the format thickness by displacement of one or several drive rollers in the region of a partially solidified strand can provide the necessary information.

CSP-installations (compact-strip-plants), billet strand casting machines with drive stands in form of segments and slab casting machines (with Cyber-Link segments), the format thickness can be changed by displacing a support roller segment (without an independently adjustable drive roller) with an adequate speed in the region of the partially solidified strand.

In slab casting machines, the change of the format thickness by displacement of a segment (with an independently adjustable individual roller) with an adequate speed in the region of the partially solidified strand, indicates the displacement of the liquid core volume.

A further casting parameter can be determined when measurement signals are based on a change of a stop plug position or a value position in an intermediate receptacle in front of the continuous casting mold. The change of the stop plug position produces displacement of the volume that can be detected.

Another measurement possibility consists in that measurement signals are based on changes of a melt level in the continuous casting mold. This measure also can indicate displacement of the volume.

It is further contemplated that measurement signals are based on changeable volume of liquid metal that flows between an intermediate receptacle and the continuous casting mold. Thereby, corresponding feedbacks are produced in the strand and the strand crater.

An indirect measurement of the volume displacement is effected with measurement signals based on changes of clamping forces between support roller pairs or support roller segment sides. Here, the conclusion with respect to volume displacements is possible, though the support roller segments or support roller pairs do not actively act on the displacement of the core liquid volume.

According to a further embodiment, dependent on the calculation model, an automatic adjustment of a support roller segment or an adjustable support roller is carried out. Thereby, the above-discussed adjustment of changeable casting parameters becomes possible.

The use of measurement results as a feedback for a control activity consists in that a sequence of position or force changes in a same system direction on the strand is undertaken from bottom upwards or in reverse.

A device for determining a position of solidification point in a strand of liquid metal, in particular of liquid steel, proceeds from a known device with an intermediate receptacle, with a continuous casting mold for a billet, ingot, bloom, preliminary section, thin slab, or slab strand format, and with support roller segments or roller pairs with drive support rollers.

The object of the invention is achieved in that there are provided signal transmitters in hydraulic piston-cylinder units of the support roller segments or of adjustable, free-running, or drive individual rollers, and which are connected with a central memory and data processing unit in which measurement result are processed, and a calculation model is used for determining a momentary

position of a core liquid volume inside still liquid strand. Thereby, there is provided means for indirect measurement of casting parameters and direct formation of a calculation model.

According to an embodiment of the device, a support roller segment without independently adjustable drive separate support roller on a loose side, is adjusted, dependent on a position and width of local and temporarily solidification point, by two piston-cylinder units spaced in a strand displacement direction below or above at an angle to the strand displacement direction.

According to a further development, the independently adjustable, drive support roller pair on a loose side, in addition to adjustment of the mentioned above support roller segments, dependent on the position and the width of the local and temporarily solidification point, is adjusted with a piston-cylinder unit. Thereby, the solidification point can be locally determined by a transition from reaction to non-reaction.

The drawings show embodiments of the invention on the basis of which the method would be explained in detail.

The drawings show:

Fig. 1 a side view of a slab continuous casting machine with signal transmitters;

Fig. 2A a support roller segment for a cast strand with a liquid core and a solidification point without an independently adjustable drive roller;

Fig. 2B degrees of freedom of a support roller segment on the loose side;

Fig. 3A a support roller segment for a cast strand with a liquid core and a solidification point with an independently adjustable drive roller;

Fig. 3B degrees of freedom of a support roller segment with a drive roller on the loose side;

Fig. 4 a separate support roller with or without drive on a partially solidified cast strand; and

Fig. 5 degrees of freedom of a non-driven and drive separate support roller, alone and in combination.

A slab continuous casting machine according to Fig. 1 serves as a basis for explaining the method of determining of a momentary position of a solidification point in a cast strand 1. Liquid steel is poured from a teeming ladder 2 in a controlled manner into an intermediate receptacle 3 from which steel flows into a continuous casting mold 4. The format 4a can represent billet, ingot, bloom, preliminary section, thin slab, slab strand formats. The cast strand 1 moves through a support roller segment 5 through a secondary cooling zone, wherein one support roller segment 5b is not adjustable. The support roller segment 5 is followed by other support roller segments 5 which are arranged along an arch passing into a horizontal. The further support roller segments 5 can be differently formed.

The strand 1 is displaced by drive support roller pairs 6, separate rollers 6a which can be adjustable, drive or non-drive. The support roller pairs 6 form groups 7 of support rollers (Figs. 2A and 2B) or support roller pairs 7a. The inflow of the liquid steel can be controlled by different positions of a stop plug

8. Thereby, the melt level 9 in the continuous casting mold is controlled. All of the above-described elements, components, and functions have a signal transmitter 10. The adjustment of a distance between rollers is effected with piston-cylinder units 11 in the cylinder chambers of which such signal transmitters are also arranged. The signals from the signal transmitters 10 are communicated to a central memory and data processing unit 12. The support roller segments 5 form, in addition, a fixed side 13a (left side) and a loose side 13b (right side).

The strand 1 is displaced from the continuous casting mold 4 through a series of support roller segments in a strand displacement direction 14.

The method is based on an indirect measurement of changeable amounts of the volume of core liquid in the strand crater 1d that can vary, in Figs. 2A and 3A, in the strand thickness 1b with a width 1c in the solidification point 1a and within the strand crater 1d, over the thickness 1b (and a non-visible width transverse to the plane of the drawings). The signal transmitters 10 send measurement signals (per unit of length or over the full length of the measurable strand crater 1b) and which are input in the central memory and

data processing unit 12 (Fig. 1) as process parameters. The signals are generated primarily by force and/or path measurements at fixed or adjustable separate support rollers 6a or at groups 7 of fixed or adjustable support roller pairs 7a. Based on the signals of one or several signal transmitters 10, a calculation model (computer program) 15 is developed for determining a momentary position of the solidification point 1a, with a subsequent, if necessary, correction of the measurement points, separately or dependent on each other, by a process control 16 in order to adapt the cast parameters to a changed situation. The measurement signal can correspond to a local change of the strand thickness 1b. Other measurement signals can be based on change of a position of the stop plug 8 or a valve position in the intermediate receptacle 3 in front of the continuous casting mold 4. Other measurement signals are generated by changes in the melt level in the continuous casting mold 4. Those can be followed by measurement signals of cooling medium temperatures in the continuous casting mold 4. Also, measurement signals, which reflect changes in the feeding volume of liquid steel between the intermediate receptacle 3 and the continuous casting mold can be taken into account. Important measurement signals are generated by changes of the clamping force between the support

roller pairs 7a or between the support roller segments 5a. Dependent on the calculation model 15, an automatic adjustment of a support roller segment 5 or of an adjustable support roller 6a takes place as a result of process signals 17. Finally, a sequence of position and force changes in a same system direction of the strand 1 from bottom upwards or (in reverse) in the strand displacement direction 14 can be effected.

The measurement signals, which are to be inputted in the calculation model 15, can be selected as separate signals, as groups of selected signals, or as a totality of all measurement signals.

According to Fig. 2A, on the fixed side 13a and on the loose side 13b, there are provided support roller segments 5 the distance between the rollers of which form the strand thickness 1b. In the strand 1 displaceable in the strand displacement direction, the strand crater 1d has a continuously reduced widths 1c up to the solidification point 1a. On the support roller segment side 5a, the support roller segment 5 is pivoted by the hydraulic piston-cylinder units 11, which engage the ends, according to Fig. 2B, as a group 7 at the bottom, inwardly or outwardly, dependent on the measurement signals, whereby a

parallel arrangement (left drawing), an inwardly pivoted position (middle drawing), with a strand 1 that becomes colder, and an outwardly pivoted position (right drawing) can be produced.

In Figs. 3A and 3B, the mentioned local changes of the strand thickness 1b take place: the separate support rollers 6a can be additionally readjusted in the arrow directions shown in Fig. 3B during the adjustment displacements according to Fig. 2B.

In Fig. 4, there are provided support roller pairs 7a individual rollers of which are adjustable. Such individual rollers can be realized as drive support roller pairs 6 wherein only one of the support rollers is adjustable. The strand 1 is shown in a horizontal position in the strand displacement direction 14, however, it applies to a transverse and//or arch-shaped region.

According to Fig. 5, such individual rollers 6a are free-running (left) or drive (right). A driven and adjustable individual roller 6a can be used in combination with a non-driven but adjustable individual roller 6a.

The determined position of the solidification point 1a leads to the handling of the strand crater 1d, as mentioned at the beginning, so that uniform distribution of alloy elements in the core zone of a respective strand format 4a of the strand 1 is produced.

LIST OF REFERENCE NUMERALS

1. Strand
1a. Solidification point
1b. Strand thickness
1c. Width of the solidification point
1d. Strand crater
2. Teeming ladder
3. Intermediate receptacle
4. Continuous casting mold
4a. Format
5. Support roller segment
5a. Support roller segment side
5b. Support roller segment without adjustment
6. Driven support roller pair
6a. Individual support roller
7. Groups of support rollers
7a. Support roller pair
8. Stop plug

9. Melt level of the continuous casting mold

10. Signal transmitter

11. Hydraulic piston-cylinder unit

12. Central memory and data processing unit

13a. Fixed side

13b. Loose side

14. Strand displacement direction

15. Calculation model

16. Process control

17. Process signals